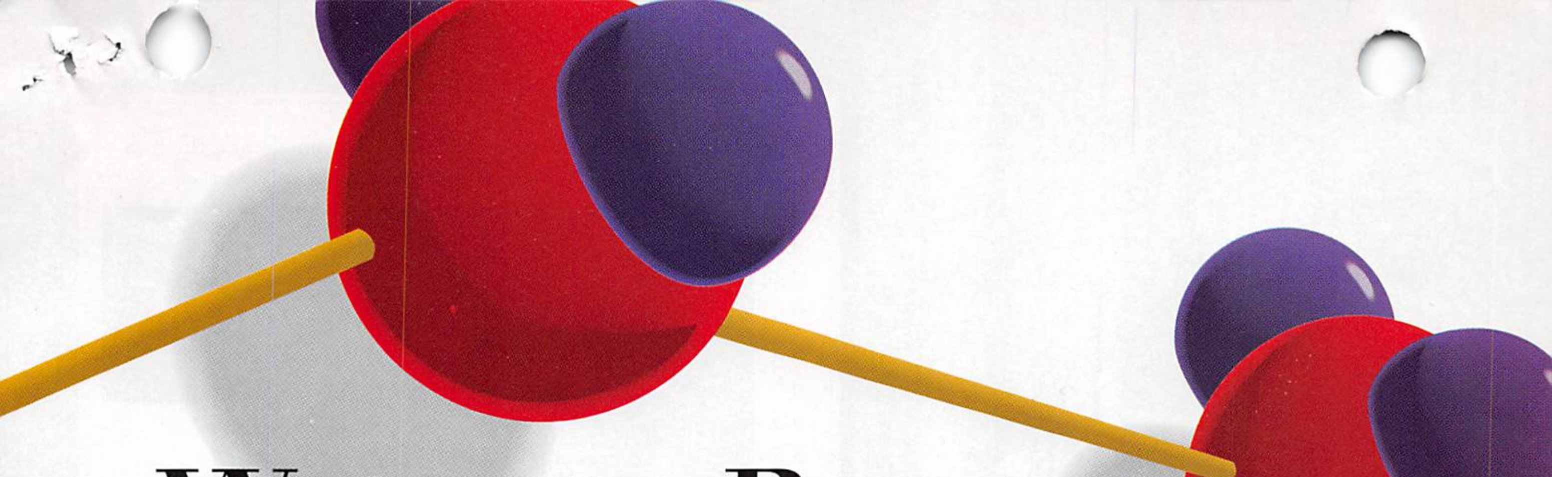


Water to Burn: The Coming Hydrogen Age?

by Kennedy Maize

Over the years, one of the classic consumer frauds has been a way to burn water instead of gasoline. Just add these pellets to your tank, or pour in this tiny can, or put this gizmo on your fuel line, and you'll be able to burn water.

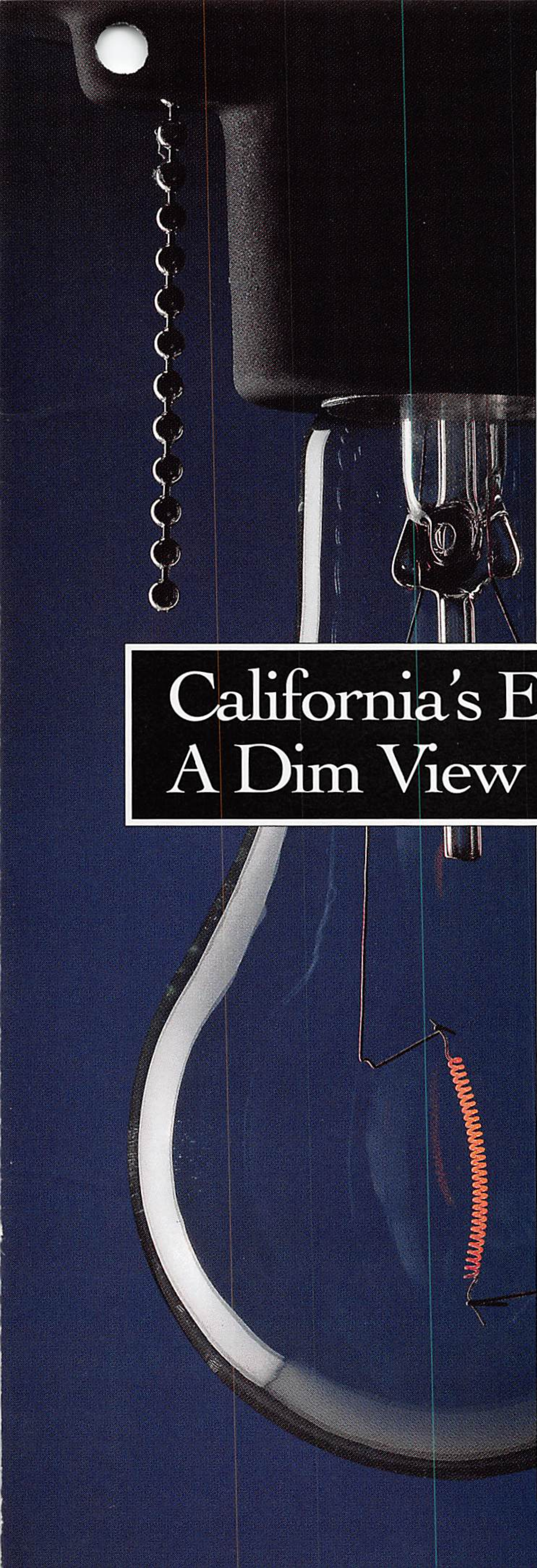
While more than a few folks have gone to jail over the years attempting to peddle technologies to turn water into gasoline, our energy future may just hinge on water to burn. It increasingly looks like hydrogen—the energetic component of H_2O—may have a major role in the future as a versatile, clean-burning fuel that can be used in applications such as powering a car, heating a home, or producing electricity.

In Oregon, the Bonneville Power Administration recently hired the architect-engineering firm of Fluor Daniel to look at using surplus, off-peak electricity to break water into hydrogen and oxygen so the hydrogen could be used to generate power at peak in a combustion turbine. In short, BPA was looking at hydrogen as a way of storing electricity.

Fluor found that while the idea is technically feasible, other generating fuels and technologies today are cheaper. Fluor concluded that hydrogen produced at 1.4 cents per kilowatt-hour would yield power at 15.8 cents per kWh. A new coal-fired plant could produce power for about 8 cents per kWh.

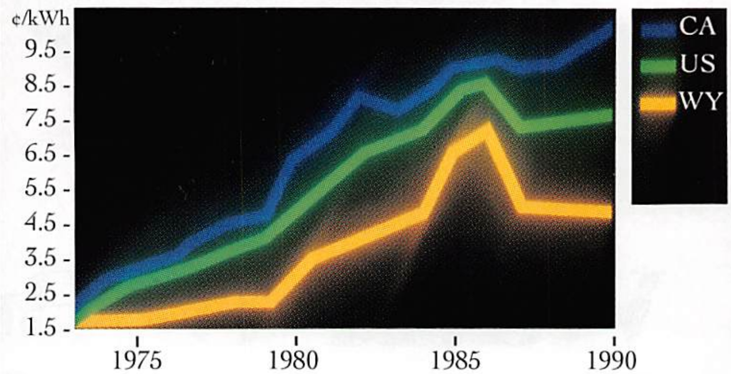
"Fluor's calculations, however, do not include benefits to the environment," notes Norm Fuller, head of BPA's hydrogen team. "Environmental savings narrow the gap between hydrogen and conventional fuels."

Those environmental benefits of hydrogen are driving the current resurgence of interest in using the simplest element in the universe to power our lives. "Environmentally," says Joan Ogden, a Princeton University energy researcher and



Price History of Electricity in California, Wyoming, and the U.S.

Source: Mills McCarthy & Associates based on EEI figures; revenues per kilowatt hour sold



The debate about national energy policy continues. Environmental professionals say using renewable energy sources such as solar, wind, and biomass is the direction to take for economic and environmental reasons. Advocates of conventional fossil fuel energy sources maintain that low cost, efficient fossil fuel combustion technologies are compatible with the environment and are vital for healthy U.S. and world economies.

California's Energy Experiment: A Dim View Of The Future.

Who is right?

With access to the same energy resources as Wyoming, California has been running an energy experiment based on renewables for over ten years now. We can unequivocally say: if California is our energy future, it doesn't work.

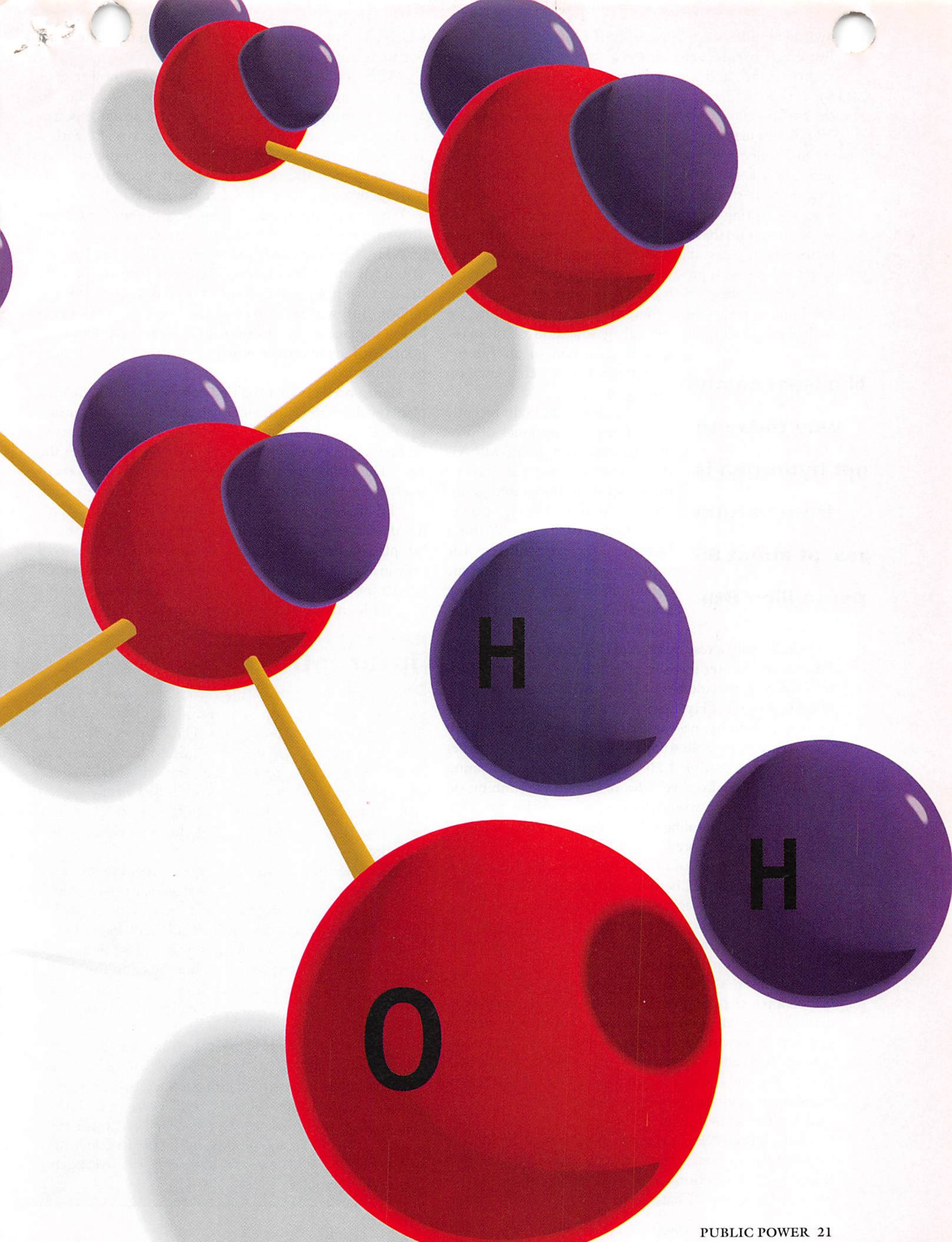
Wyoming has stuck to the tried and true principles of cost-based rate making. This graph shows the difference in price for electricity generated in California, Wyoming, and nationwide. The graph says it all.

California's electric rates soar because 3500 megaWatts of *unneeded* capacity in renewable energy generation technologies have been placed in service by order of government agencies that substitute their judgement for the marketplace.

If Californians paid the same rates as those in Wyoming, the total electric bill in California would drop more than $5 billion per year. An unjustified reliance on renewables is simply a recipe for high energy prices, high living costs, and inflation.

The answer for those concerned about economic growth and equity for people on low or fixed incomes is this: reliance on a new generation of clean-burning, efficient fossil fuel resources offers a bright energy future. Adopting California's policies would be a mistake. If California is the future – it doesn't work.

WESTERN FUELS ASSOCIATION INC.
A not-for-profit consumer-owned organization.


H
H
O

hydrogen enthusiast, "hydrogen is nearly the ideal fuel. Burning it releases zero carbon dioxide, zero sulfur, zero hydrocarbons, and zero particulates. All you generate is water vapor and a small amount of nitrogen oxides." Use the hydrogen to run a fuel cell to make electricity and the NO_x is eliminated.

Nor is electrolysis of water the only way to get hydrogen. There are other, less expensive, ways to produce the large volumes of hydrogen needed for energy production. According to Jim Birk of the Electric Power Research Institute, the least costly way today to get hydrogen is from natural gas, at about $5 per million Btu. The next step for hydrogen production will be from coal gasification, Birk predicts, at about $7-$8 per million Btu. For the long run, says Birk, there is a renewable future for hydrogen production through gasification of biomass. Birk is chairman of an Energy Department research panel on hydrogen.

The least costly way today to get hydrogen is from natural gas, at about $5 per million Btu.

Florida Power & Light recently looked at the economics of producing hydrogen along with either synthetic natural gas or methanol in an integrated gasification combined-cycle power plant fueled with coal. Without factoring in externalities, the study found that there were some economic benefits from adding a methanol plant and hydrogen recovery.

Eric Larson, a researcher and colleague of Ogden's at Princeton's Center for Energy and Environmental Studies, is very optimistic about biomass gasification to produce hydrogen. "Hydrogen as a transport fuel can be produced from biomass at lower cost than from coal and from other renewable sources," Larson wrote in a paper presented at a National Hydrogen Association meeting last March. "Fuel cell vehicles of the future running on biomass-hydrogen would be cost-competitive on a life cycle basis with gasoline-engine vehicles when oil costs $25 per barrel or more."

Biomass, Larson said in an interview, "is a lot easier than coal to gasify. It is more reactive, has more hydrogen and oxygen per unit of carbon than coal. So it reacts more quickly and at a lower temperature, which lowers the cost. Most biomass has little sulfur in it, which cuts down a bunch on cleanup costs."

Last March, the National Hydrogen Association presented a paper outlining the economics of several applications of hydrogen technology, including electric generation. For utilities, the study found that high-temperature fuel cells—molten carbonate and solid oxide electrolyte systems—using hydrogen are most attractive. Phosphoric acid fuel cells are probably better suited for vehicles, the study found.

According to NHA Research Director Robert Mauro, "it looks like molten carbonate is the only central station technology. Phosphoric and solid oxide will be for remote applications." That's good news for public power, which has spearheaded commercialization of molten-carbonate technology.

Mauro said the economics of hydrogen power generation are tied "to the externalities game." According to Mauro, existing generating technologies produce power at about 9.1 cents per kWh, assuming a plant with a 10,300 Btu/kWh heat rate. Depending on the fuel cell technology and the cost of hydrogen, generation from hydrogen "comes in at 10-14 cents per kWh."

While those figures don't look very impressive for hydrogen, they look better when externalities are factored in. NHA's analysis used figures developed by the University of Miami's Clean Energy Research Unit to estimate the costs of pollution damage. Those figures are $9 per million Btu, which means that the "average cost of pollution damage from a fossil plant is 9 cents per kilowatt-hour," making hydrogen much more attractive, according to Mauro.

Mauro predicts that the first central station hydrogen plants will get their hydrogen from conventional natural gas pipelines. Shipping hydrogen with gas is quite easy, he said, and it is easy to strip the hydrogen off from the gas. "Then will come the gasifier, first using coal and eventually using biomass, the renewable option," Mauro said.

"Hydrogen and fuel cells will penetrate first in polluted areas such as Southern California," Mauro said, "displacing oil and gas generation. It will displace coal only in an area where there is lots of cheap biomass. You'll need a lot of biomass, basically whatever you can get."

Utilities may also face competition from fuel cells, ac-

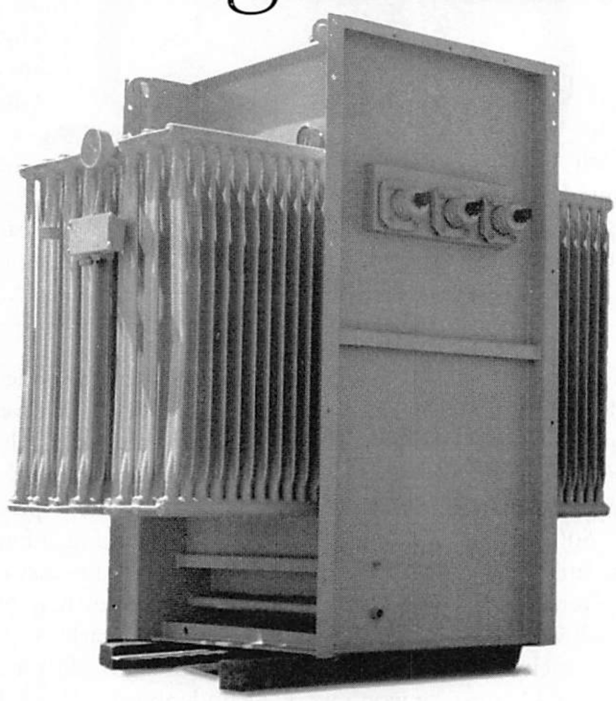
International R&D

Germany has the largest government-backed hydrogen research program, according to a recent Energy Department report to Congress. The German program, driven in part by the strong political position of the Green party in favor of hydrogen, amounted to 53 person-years in 1991. According to Jim Birk of the Electric Power Research Institute, much of the German effort in hydrogen has been on chemical electrolysis of water.

Japan has the second largest government hydrogen research program, at about 26 person-years or half the size of the German program. And the U.S. rates third, at 13 person-years. Birk, who heads EPRI's storage and renewables department, notes that EPRI does not have a hydrogen program at all. But, he adds, the electric utility industry's research arm is doing work in other areas that relates to hydrogen, such as work on fuel cells and renewables.

At DOE, direct hydrogen research amounts to about $1.5 million, most of it the result of the 1990 Matsunaga Act, named for the late Democratic Senator Spark Matsunaga of Hawaii. According to Birk, the act was designed not just to push hydrogen research, but "as an integrating bill, to help come up with an integrated, national approach" to hydrogen research. PP

Homely as it is, your electrical transformer should never be taken for granted.



Sunbelt Transformer has flexible plans to sell or rent new or remanufactured transformers fast.

Transformers don't fail often, but when they do they are sorely missed. The effects can be catastrophic: blackouts, spoiled food, idle assembly lines.

Be prepared with Sunbelt Transformer, which specializes in the sale and rental of mid-voltage oil-cooled and dry-type transformers up to 69kV.

Order a brand new transformer or send us your old one for repair. Either way you'll receive quick quotes and reliable service.

We maintain a complete inventory of more than 3,000 core units. And our commitment to Total Quality Management enables us to offer a unique two-year warranty on our remanufactured oil-filled transformers (double the industry standard).

So consider your transformer from time to time. And consider ours.

Call 800-433-3128. Fax: (817)771-5719. Or write Sunbelt Transformer, P.O. Box 1500, Temple, TX 76503-1500.

NAED ASSOCIATE

EASA ELECTRICAL APPARATUS SERVICE ASSOCIATION

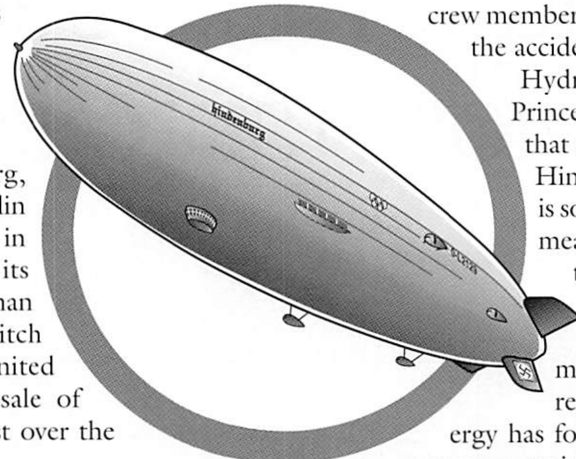
Ask about our unique two-year warranty.

SUNBELT TRANSFORMER

P.O. BOX 1500 • TEMPLE, TX 76503 • 24 HR. • U.S./CANADA/MEXICO 1-800-433-3128 • FAX (817) 771-5719

The Hindenburg

The image of the dirigible Hindenburg crashing in flames at Lakehurst, N.J., on May 6, 1937 has a remarkable persistence. Both the powerful image of the large airship engulfed in flames and collapsing and shriveling as it died, as well as the emotion-laden voice of the broadcaster on the scene, have stayed in the mind and burdened the case of hydrogen's advocates for years. Nor did a mid-1970s big-budget motion picture reprise of the Hindenburg event help the hydrogen advocates.



Ironically, the Hindenburg, built by Luftschiffbau Zeppelin in Friedrichshafen, Germany in 1936, was designed to get its lift from helium. But the German airships were forced to switch to hydrogen because the United States had embargoed the sale of helium to Germany in protest over the Hitler government.

Another irony was that the hydrogen-filled Graf Zeppelin made regular, safe crossings of the Atlantic from 1928 to 1937, when the Hindenburg disaster ended all use of airships in passenger service.

The wreck of the Hindenburg was a large disaster for its time, but looks somewhat smaller by the standard of today's aircraft industry. Violating a safety rule by attempting to dock in a thunderstorm, the explosion of the Hindenburg killed 36 passengers and 22 crew members. Yet 65 people on board survived the accident.

Hydrogen researcher Joan Ogden at Princeton University always points out that one reason many were saved in the Hindenburg disaster is that hydrogen is so light that it disperses quickly. That means it is hard to maintain concentrations that can fuel a fire. Jim Birk at the Electric Power Research Institute in Palo Alto, Calif., makes the same point, noting that research by the Department of Energy has found that "hydrogen tends to disperse very rapidly." PP

cording to Maruo. NHA's analysis compared a conventional 1,800-square-foot all-electric house in the Washington-Baltimore area buying its power from either Baltimore Gas & Electric or Potomac Electric Power Co. against the same house equipped with a four-kW fuel cell with an installed cost of $1,600 and a five-year life. Assuming that two-thirds of the utility electricity comes from fossil fuels and using the University of Miami's externalities estimate, then the fuel cell would cost $11,500 over the five-year life, while the electricity would cost $11,200 to $11,300. "In other words," said Mauro, "it won't work in the Baltimore-Washington area, but it very well might in Manhattan or San Diego."

If the residential fuel cell also becomes a cogenerator and sells power into the grid, then "this raises the issue of bypass to utilities," said Mauro. "They will fight that with everything they have. They'll charge for connections, charge for the use of the transmission and distribution system, you name it. They'll fight it tooth and nail."

Energy futurists have long been bemused by hydrogen because it has so many attractive features. As one 1976 study of hydrogen observed, "When the criteria for an ideal fuel are considered together in the abstract—inexhaustibility, cleanliness, convenience, independence from foreign control—it often seems to many people as if nature intended mankind to use hydrogen as a fuel."

But hydrogen has a dark side as well. First, it is not a basic energy resource. It can't be found chemically free in nature, so it can't be obtained without using some other form of energy to liberate it. It is an "energy carrier"—a means to transport and store energy derived from other sources, much like electricity.

Hydrogen has lower energy density than fossil fuels, meaning it is difficult to store, particularly in vehicles. While it can be stored much as natural gas, storing it as a gas would not be practical for cars. Most hydrogen experts are looking at hydrogen "slush," a partially liquified product, as the answer for vehicle fuel. Others believe metal hydrides may work, or that activated carbon can perform the task.

The 1937 fiery explosion of the German dirigible Hindenburg certainly has reinforced the message that hydrogen can explode spectacularly. (See sidebar.) The danger of hydrogen was reinforced by the Three Mile Island nuclear disaster in 1979, when there was great concern that a hydrogen explosion could crack open the containment dome and spread nuclear contamination far and wide.

Despite its potentially explosive nature, hydrogen had a brief heyday in the mid-1970s during the midst of the energy crisis years. At that time, independent analysts and government studies were describing the "hydrogen economy" of the future as a competitor to the "plutonium economy" nuclear advocates were forecasting. Hydrogen would be the energy carrier when carbon-based fuels were inevitably depleted.

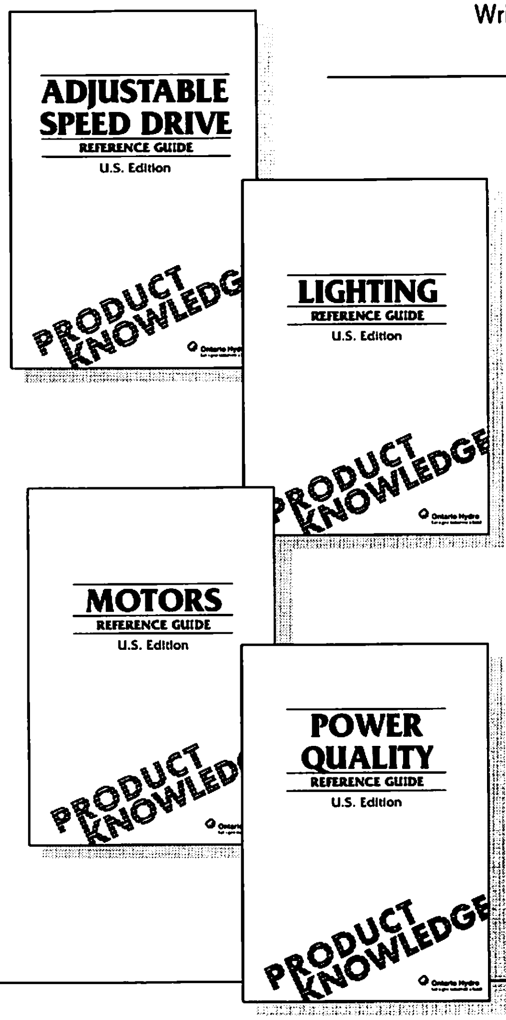
As an NHA paper last March observed drily, "the picture of the '70s is not the vision of today." Predictions of the death of fossil fuels proved to be greatly exaggerated, as the 1986 free fall in oil prices demonstrated. Hydrogen never materialized as an economical energy carrier and its use today is largely in industrial processes.

Interest in hydrogen has resurged since the late 1980s, driven by hydrogen's environmental qualities and by the

PUT QUICK, ACCURATE ELECTRIC PRODUCT INFORMATION AT YOUR FINGERTIPS.

Product Knowledge Reference Guides

The American Public Power Association and Ontario Hydro have edited these four unique electric product knowledge reference guides specifically for U.S. audiences. Each of these handy 5" x 7" guides offer concise, reliable technical information and contain charts, graphs and a bibliography. They may be used as training tools for utility personnel or as an information source for customers. Written by experts, they are accurate and easy to understand.



Adjustable Speed Drive Reference Guide
Adjustable speed drive technology offers great potential for energy savings and improved process control. This guide can be used by utility personnel to help customers define potential energy saving opportunities, understand electrotechnologies and choose products that will maximize benefits. 90 pages.

Lighting Reference Guide
This guide provides information to help utilities advise customers on the most efficient and effective modern lighting systems. It covers residential, commercial, industrial and outdoor applications. 101 pages.

Motors Reference Guide
This guide provides useful information for utilities to use in advising customers on the selection, operation and maintenance of motors, one of the largest areas of industrial energy consumption. 76 pages.

Power Quality Reference Guide
This guide is an information source on power quality, a critical element of customer satisfaction. The increasing use of highly sensitive electronic equipment and the growing availability of products that may cause disturbances in the electrical power system have reinforced the need for achieving the highest standards of reliability and power quality. The guide may be used as a training aid for utility personnel or as an informational source for large industrial and commercial customers. 147 pages.

Cost to APPA Members: $25 each; $20 if ordering all four (the set for $80)
To Non-members: $35 each; $27.50 each if ordering all four (the set for $110)

Quantity Ordered
_____Sets of all Four Books
_____Lighting Reference Guide
_____Motors Reference Guide
_____Adjustable Speed Drive Reference Guide
_____Power Quality Reference Guide

Name ____

Organization's Name: ______________________________

Shipping Address: _________________________________

____

Billing Address: ___________________________________

Phone Number: ______________________ APPA Member _____Yes _____No

RETURN TO: APPA Publications Department, 2301 M St. N.W., Washington, DC 20037-1484, 202/467-2926

long experience the National Aeronautics and Space Administration has piled up with hydrogen in the space program. As an NHA paper notes, "the first hydrogen economy, once envisioned for the future, already exists in space. Hydrogen is used for propulsion, electric generation, water production and other onboard spacecraft functions. Terrestrial applications are next."

EPRI's Jim Birk, in a paper to be discussed at the September meeting of DOE's Hydrogen Technical Advisory Panel, has laid out how he sees the transition to hydrogen occurring. In an interview, Birk described this paper as a "strawman" that he is offering mostly to generate discussion. "The real problem," he said, "is that in the past folks haven't articulated a vision for hydrogen that makes a lot of sense."

The first step for hydrogen, Birk says, will come in "co-firing hydrogen with natural gas for the purpose of lowering emissions." It is now well understood that adding hydrogen to gas will lower NO_x emissions. Today, Public Service of Colorado is testing a mixture of 15 percent hydrogen (by volume) with compressed natural gas vehicle fuel in Denver. The fuel is called "hythane."

"If it is economically viable to lower emissions with hydrogen, we have automatically got an infrastructure that gets hydrogen into the marketplace," says Birk. "Then private enterprise will find new ways to use it. It's like electricity, where the electric appliances were invented because the electricity was already being delivered to the home."

Next, Birk believes, will come aviation. Hydrogen, he says, "is a great aviation fuel." NASA is attempting to demonstrate that technology through its National Aerospace Plane, which will be fueled by hydrogen slush. Hydrogen's environmental benefits will be a powerful inducement here, says Birk. "Los Angeles airport is the equivalent to 300,000 cars," he notes.

Vehicles will come next, either with hydrogen burned in conventional internal combustion engines or with small fuel cells powering electric motors, or with hybrid engines. NHA has estimated that adding externalities costs to conventional vehicles makes all of the hybrid hydrogen technologies it studied more economical than gasoline-fueled cars. Without factoring in pollution costs, gasoline wins every time.

Finally, electric utility applications will come along, using gasified biomass as a hydrogen source. "Utilities are bulk fuel users," cautions NHA's Mauro. "They won't switch to hydrogen until they have to. Hydrogen can be a pain in the neck to use and it won't make an impact until its unique properties are valued highly enough."

Is the promise of an endless, renewable supply of hydrogen fuel a threat to utility demand-side-management programs? Not according to Mauro. "Conservation is very critical," says Mauro. "We need a lot of it. The renewable resources are not all that abundant and we can conserve tremendously."

Princeton's Ogden offers a somewhat different vision of hydrogen's future. Ogden is counting on the development of solar photovoltaic technology to drive the transition to hydrogen. In Ogden's vision of the future, vast fields of photovoltaic arrays would generate power to electrolyze water from underground aquifers. Pipelines would carry the hydrogen from the solar fields to the rest of the country.

In Ogden's scenario, hydrogen pipelines would replace high-voltage transmission of electricity. "We've calculated that it is about one-fourth as expensive to pipe hydrogen across long distances as it is to transmit electricity the same distance," she said in a recent article.

EPRI's Birk isn't entranced with Ogden's hydrogen visions. "I see the transition to renewables," he said, "but not photovoltaics. If you have electricity and need hydrogen at the end use, it might make sense. But if you want electricity at the end, it makes no sense to get to it by using electricity to make hydrogen and then using the hydrogen to make electricity. You lose half the energy."

Science and technology may leapfrog both Birk and Ogden. Researchers at Michigan State University have looked at plant photosynthesis as a model for using sunlight to get hydrogen without electrolysis. H. Ti Tien has used a thin film cadmium selenide semiconductor painted on nickel foil to produce hydrogen. Light excites electrons in the semiconductor that travel to the nickel where they break sea water into hydrogen and other products.

In the vehicle area, a New Jersey firm, H Power, has come up with a novel way to store hydrogen to supply a fuel cell that could jump start hydrogen as a vehicle fuel. The company won a worldwide patent for a system to get hydrogen from an iron and water mixture.

As iron combines with water to form rust, it gives off hydrogen, something scientists have known for generations. But to get the kind of reaction you would need to generate significant amounts of hydrogen, you need high temperatures, around 700 F. H Power has come up with a catalyst that allows recovery of hydrogen at 100 degrees.

The technology would allow a hydrogen-fueled vehicle to have a simple tank that consists of a coarse iron powder and water. When the iron was fully oxidized, the owner could turn in this bucket of rust at the filling station and get a new one. Then natural gas could be used to easily reduce the rust back to iron.

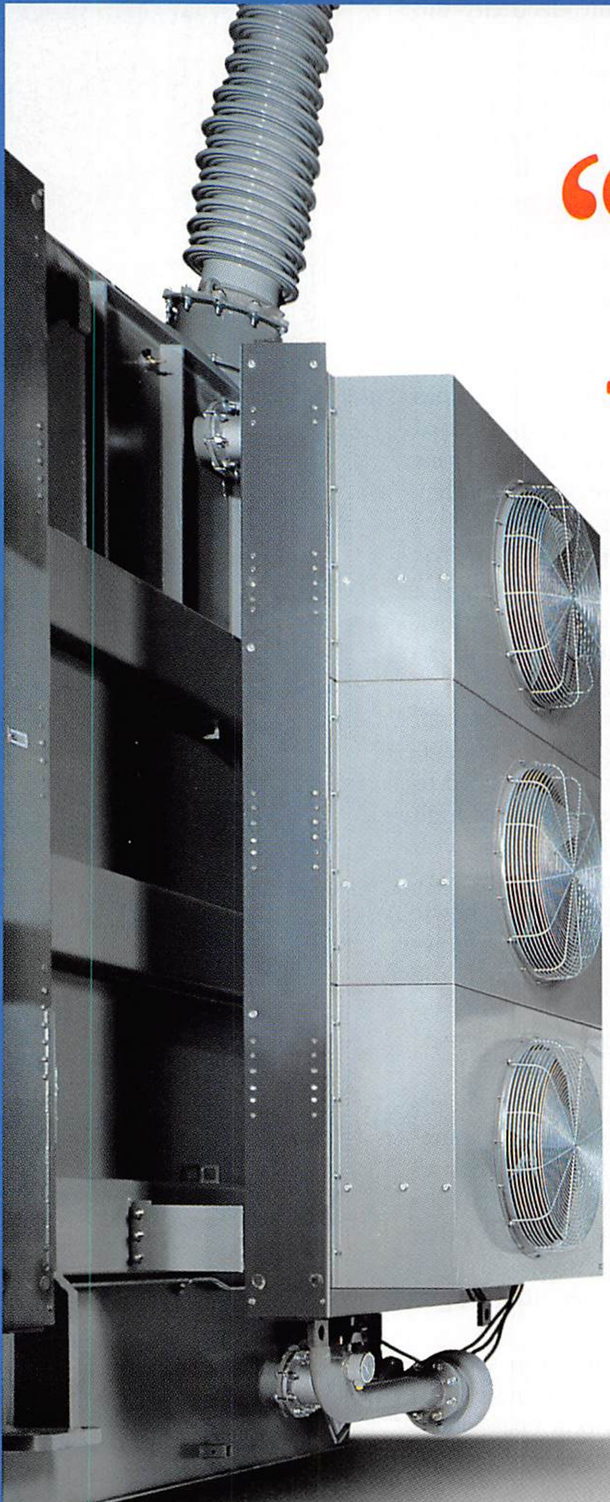
The rustmobile is "quite interesting," says Princeton's Eric Larson. "They had been telling us they had something that was revolutionary, and that kind of turned us off. But when they finally told us about the details, it may make sense. They claim they will have a system that will work with a fuel cell at small scale in a year or two."

Larson isn't the only one who is interested; Rolls Royce is a partner in the project.

Is hydrogen the fuel of the future? It is too soon to tell. But those who work with it have tremendous enthusiasm about the first element on the periodic chart of the elements. And hard-headed business types are putting down their bets on hydrogen, as well. The National Hydrogen Association was formed in 1989 by companies such as Airco Industrial Gases, Allied-Signal Aerospace, Union Carbide, and Air Products & Chemicals.

In a recent paper on the future of hydrogen, NHA concluded: "Hydrogen application energy technologies are not a futuristic vision. Impressive applications that will favorably impact our future economy and environment are currently under development." PP

Kennedy Maize is an energy writer in Knoxville, Md.



"A"

Only One Company

You Can Count on Cooper Power

NEMA
MEMBER